Vol. 1 (2008) *Acta Physica Polonica B Proceedings Supplement* No 3

OPEN CHARM PRODUCTION AT RHIC*

Xin Dong

Lawrence Berkeley National Laboratory
MS70R0319, One Cyclotron Road, Berkeley, CA 94720, USA

(Received October 16, 2008)

I briefly review the recent experimental progress on the open charm production in proton–proton and nucleus–nucleus collisions at RHIC. Comparisons with theoretical predictions leave some unsettle issues, which call for precise measurements on directly reconstructed open charm hadrons.

PACS numbers: 25.75.Dw, 13.20.Fc, 13.25.Ft, 24.85.+p

1. Introduction

Heavy quark production is believed to be a powerful test for pQCD calculations in elementary collisions. The theoretical predictions for heavy quark production cross-section at high energies are intensively reported in [1]. In heavy ion collisions, charm yields are expected to be scaled by N_{bin} since most charm quark pairs are created in the initial hard processes. Because heavy quark is not likely to be modified in the QCD medium due to its heavy mass, heavy quark collectivity can reveal more early stage information than light quarks indicate, and thus indicate the early thermalization degree of the light quarks [2]. Measurements on open charm production also provides an important reference for charmonium production study, which is believed to be a robust signal of QGP.

2. Experimental progresses

PHENIX and STAR experiments at RHIC reported their recent measurements on the total charm production cross-section from $p+p$ and Au+Au collisions at 200 GeV [3, 4]. Fig. 1 shows the current available world data on the charm production cross-section per nucleon–nucleon collision *vs.* the collision energy, compared with three typical theoretical calculations from PYTHIA, NLO pQCD and FONLL. At 200 GeV region, the uncertainty

* Presented at the XXXVII International Symposium on Multiparticle Dynamics, Berkeley, USA, August 4–9, 2007.

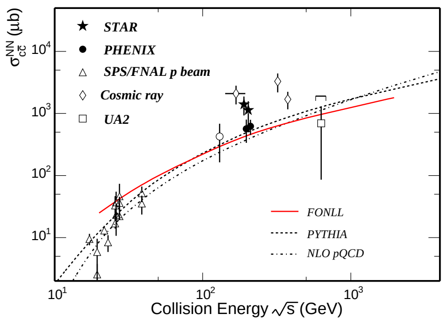

Fig. 1. Total $c\bar{c}$ cross-section per nucleon–nucleon collision *vs.* the collision energy. The low energy data points are selected from fixed target experiments [5]. The diamonds are taken from two cosmic ray measurements [6].

from experimental data is still big, and at present, this is limited by the current detector technique and coverage. Although those data points are above the typical calculations from pQCD, they agree with the calculations with large uncertainties [1]. PHENIX and STAR also reported the charm cross-section measurements in various centralities in Au+Au collisions, and within current uncertainties, both experiments conclude the charm production approximately obeys N_{bin} scaling in heavy ion collisions.

Fig. 2 left panel shows the recent results on the nuclear modification factor R_{AA} for non-photonic electrons in central Au+Au collisions from PHENIX [7] and STAR [8]. The results illustrate a significant suppression on non-photonic electron production at high p_{T} in central Au+Au collisions. The theoretical calculations (a typical one shown as the band in the figure)

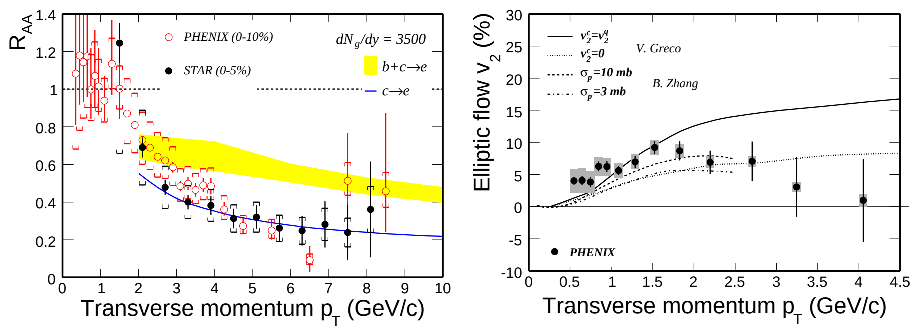

Fig. 2. Left: Measurements of nuclear modification factor in central Au+Au collisions for non-photonic electrons by PHENIX and STAR, compared with a typical theoretical calculation within gluon radiation energy loss mechanism. Right: Measurements of elliptic flow in minibias Au+Au collisions for non-photonic electrons by PHENIX, compared with theoretical predictions.

for the non-photonic electron R_{AA} with gluon radiation energy loss mechanism [9] cannot re-produce its strong suppression in central Au–Au collisions if the bottom contribution is taken into account as what is given by pQCD calculations.

This phenomenon indicates charm quark may also lose a significant amount of energy when tranversing the hot dense medium, which arouses theorists to revisit the energy loss mechanism. Recent calculations shows the elastic collision energy loss, which was believed to be small, is of importance for charm quarks at RHIC energy [10]. And furthermore, the gluon radiation cannot be treated as induced by a static medium since the collisions energy loss is not neglegible. A first step of combining the calculations of gluon radiation and collisional energy loss in a "dynamic" QCD medium was reported in [11], and the numerical result shows the additional energy loss due to the "dynamic" medium is comparable to that in a static medium. It still needs significant efforts in this direction.

Fig. 2 right panel shows the results on the elliptic flow (v_2) of non-photonic electrons in minimum bias Au+Au collisions from PHENIX [7], compared with two groups of predictions [12]. At the p_T beyond 3 GeV/c, there are big uncertainties on the experimental data points, as well as the contribution from bottom quarks. The data points below 2 GeV/c favors those theoretical calculations with large charm quark v_2 or large partonic interaction cross-section for charm quarks, indicating that the charm quark may have a finite v_2 in heavy ion collisions. However, the current uncertainty on data points cannot allow us to draw a quantitative conclusion on charm quark v_2. In the most interesting region for charm quark collectivity study (below $\sim$ 3 GeV/c), systematic errors through non-photonic electron approach are significant, which limits our physics achievements without direct topological reconstruction of open heavy flavor hadrons.

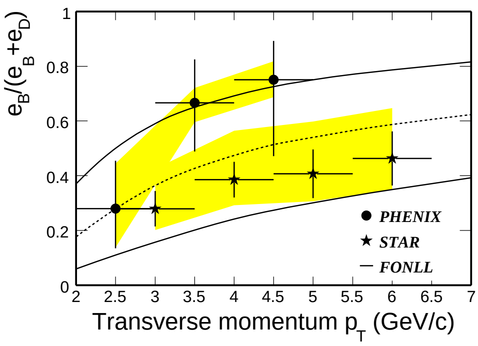

Fig. 3. Preliminary measurements of the ratio of the bottom decay electrons to total non-photonic electrons from PHENIX and STAR, compared with FONLL calculations.

The non-photonic electron measurement cannot avoid the contamination from bottom decays. Theoretically, the crossing point between $p_{\rm T}$ spectra of charm decay electrons and bottom decay electrons may vary from $\sim$ 3–10 GeV/c [1]. To disentangle the relative bottom contribution in the electron spectrum experimentally becomes important in current electron approach technique. Recently, PHENIX and STAR reported preliminary results on this by measuring the e–h invariant mass and azimuthal correlations, respectively [13, 14]. Fig. 3 shows the results compared with FONLL calculations. Within large uncertainties, the data points are consistent with the FONLL predictions. But this still cannot allow us to precisely interpret the R_{AA} and v_2 measurements.

3. Summary and outlook

The heavy flavor programme has started at RHIC extensively. Plenty of new and surprising results on open charm production at RHIC have been reported in recent conferences and publications. However, the current experimental data and their interpretation have large uncertainties. Precise measurements of spectrum and v_2 of reconstructed charm hadrons in a wide $p_{\rm T}$ range are needed. So current sub-detector upgrade proposals in pipe for PHENIX and STAR detectors are very important.

REFERENCES

[1] M. Cacciari, P. Nason, R. Vogt, *Phys. Rev. Lett.* **95**, 122001 (2005); R. Vogt, *Eur. Phys. J.* **ST155**, 213 (2008) [`arXiv:0709.2531 [hep-ph]`].
[2] X. Dong *et al.*, *Phys. Lett.* **B597**, 328 (2004).
[3] A. Adare *et al.* [PHENIX Collaboration], *Phys. Rev. Lett.* **97**, 252002 (2006).
[4] J. Adams *et al.* [STAR Collaboration], *Phys. Rev. Lett.* **94**, 062301 (2005); C. Zhong *et al.* [STAR Collaboration], *J. Phys. G.* **34**, S741 (2007).
[5] S.P.K. Tavernier, *Rep. Prog. Phys.* **50**, 1439 (1987), and references therein.
[6] I.M. Dremin, V.I. Yakovlev, *Astroparticle Phys.* **26**, 1 (2006).
[7] A. Adare *et al.* [PHENIX Collaboration], *Phys. Rev. Lett.* **98**, 172301 (2007).
[8] B.I. Abelev *et al.* [STAR Collaboration], *Phys. Rev. Lett.* **98**, 192301 (2007).
[9] M. Djordjevic, M. Gyulassy, S. Wicks, *Phys. Rev. Lett.* **94**, 112301 (2005); B.W. Zhang, E.K. Wang, X-N. Wang, *Phys. Rev. Lett.* **93**, 072301 (2004); N. Armesto *et al.*, *Phys. Rev.* **D71**, 054027 (2005).
[10] S. Wicks *et al.*, *Nucl. Phys.* **A784**, 426 (2007).
[11] M. Djordjevic, U. Heinz, *Phys. Rev.* **C77**, 024905 (2008) [`arXiv:0705.3439 [nucl-th]`].
[12] V. Greco, C.M. Ko, R. Rapp, *Phys. Lett.* **B595**, 202 (2004); B. Zhang, L.W. Chen, C.M. Ko, *Phys. Rev.* **C72**, 024906 (2005).
[13] Y. Akiba *et al.* [PHENIX Collaboration], Heavy Flavor Workshop, Berkeley, 2007.
[14] X. Lin *et al.* [STAR Collaboration], *J. Phys. G* **34**, S821 (2007).